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A BRIEF INTRODUCTION TO COQ

The Coq Proof Assistant and Schedulability Analysis

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RECAP

LAST TIME

- → proof assistants
- → functional programming in Coq
- → applications of Coq
- → PROSA and RT-Proofs

FORMER OUTLOOK

→ lecture notes for Steffen Reith, incorporate review

→ incorporate linear temporal logic

→ Steffen Reith's review

→ incorporate Steffen Reith's review on the PROSA working directory

→ tutorial on `Gallina` and `SSreflect` (4 person days)

→ formally proof the Kaiser's EDF scheduler in PROSA hopefully less then ($\approx 1'320$ LOC)

→ see at what is the best way to approach the complete kernel

FORMALLY PROVE KAISER'S EDF-SCHEDULER

PROSA FORMAL SCHEDULABILITY ANALYSIS

- → basic tools from logic
- → precise claims about programs
- → functional programming methods of programming and logical reasoning about programs

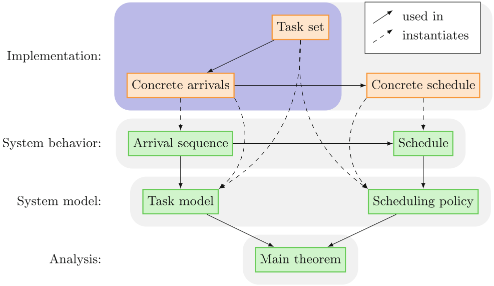

Figure: PROSA layers. Source:[1]

MAIN THEOREM: PROSA ECRTS16 ARTIFACT EVALUTAION

practical specification: correctness of the proof

→ EDF-specific interference bound definition and proof of termination and correctness of Bertongna and Cicerei's RTA for FP scheduling

→ **definition and proof of termination and correctness of Bertongna and Cicerei's RTA for EDF scheduling** ($\approx 1'320$ LOC)

my current working directory:
https://gitlab.cs.hs-rm.de/almeroth/prosa_working_dir
due to documentation including all listings ($\approx 13'070$ LOC)

LTL AND MULTIPROCESSOR SCHEDULING

LTL AND MULTIPROCESSOR SCHEDULING

Taxonomy of Multiprocessor Scheduling

- → fixed task priority
- → fixed job priority
- → dynamic priority

Idea: apply linear temporal logic to verify static and dynamic priority scheduling methods.
Suggestion: Predicate logic-based approaches fail for dynamic priority scheduling methods.

WHAT IS LTL

- Linear temporal logic is linear like a linear tree (graph)
- apply this linearity approach to a discrete time in a state-space system
- LTL's origins are in the natural language descriptions
- natural numbers $\mathbb{N}$ represent a moment in time

Example: typical temporal operators

- $\bigcirc\phi$ means ϕ is true in the next moment
- $\Box\phi$ means ϕ is true in all future moments
- $\Diamond\phi$ means ϕ is true in some feature moment
- $\phi\mathcal{U}\psi$ means ϕ is true until ψ is true

Goal: verification of dynamic priority scheduling methods

MUTIPROCESSOR SCHEDULING

PROBLEM

In *hard real-time systems* we say a process or task is defined as an sequential execution of a program or a job on a processor. The execution ends after a *finite number of steps*.

→»One big train of commands has to pass in a finite amount of time.«

Definition

Multiprocessor scheduling can be viewed as attempting to solve two problems.

(i) The *allocation problem*, or on which processor the task should execute.

(ii) The *priority problem*, or in what order with respect to jobs of tasks each job should be executed.

PRIORITY PROBLEM

Kasier's encapsulated EDF-scheduler [3]

- → real-time as in [1]
- → hierarchical (local and global distinction)
- → multi-core (in the real-time-sense)
- → EDF (earlines deadline first on a local level)
- → sporadic
- → disruptive

Main theorem: correctness of analysis although it is a deductive derivation

PROBLEM: DEFINE A JOB OR TASK

Definition

Let

$\delta_p \in \mathbb{N}$ be a periodic disruptive process and

$\delta_s \in \mathbb{N}$ be an asporadic disruptive process.

Let $P := \{1, \cdots, n\} \subset \mathbb{N}^n$

be a job, a set of disruptable processes

with fixed priority order ascading.

Let $\delta p_i \in \mathbb{N}$, for $i = 1, .., n$ denote the period and

$\delta e_i \in \mathbb{N}$ for $i = 1, .., n$ denote the execution time of a proces.

MULTIPROCESSOR SCHEDULING ALGORITHM

Definition

We say a multiprocessor scheduling algorithm σ is given by

$$\sigma : \mathbb{N}^n \times \mathbb{N}^n \longrightarrow \mathbb{N} \times \{1, 2, \cdots, m\} \tag{1}$$

$$\forall i, \delta e_j \in \mathbb{N} \quad (i, \delta e_j) \mapsto (t, k) \in \mathbb{N} \times \{1, 2, \cdots, m\}. \tag{2}$$

map time i and execution time δe_i to time-sequence t and processor k

MULTIPROCESSOR SCHEDULING ALGORITHM

A scheduler satisfying the EDF-regulation

$$U(P) = \sum_{i=1}^{n} \frac{\delta e_i}{\delta p_i} \leq \frac{\Delta e_{sv}}{\Delta p_{sv}} \tag{3}$$

is called feasible.

Theorem

A hard-real-time, hierarchical, multi-core, EDF, sporadic and disruptive time scheduler is feasible iff

$$\sum_{i=1}^{n} \lfloor \frac{t}{\Delta p_i} \rfloor \Delta e_i \leq \lfloor \frac{t}{\Delta p_{sv}} \rfloor \Delta e_{sv} + \max(0, t mod \Delta p_{sv} - \Delta e_s - \Delta e_p). \tag{4}$$

OUTLOOK

apply the theorem of Akra -Bazzi

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